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Amplification With Digital Noise Reduction and the Perception of Annoying and Aversive Sounds

Catherine V. Palmer, PhD, Ruth Bentler, PhD, and H. Gustav Mueller, PhD

Hearing aid users report difficulties using their hearing aids in noisy environments. Problems include understanding speech, loudness discomfort, and annoyance with background noise. Digital noise reduction algorithms have been promoted as a method to solve speech understanding and comfort in noise problems. Research has failed to find improved speech understanding in noise. Little is known about how digital noise reduction affects noise annoyance and aversiveness. The goals of this investigation were to determine how a specific digital noise reduction system affects hearing aid users' perception of noise annoyance and aversiveness and to compare their perceptions to those of normal-hearing listeners. Ratings of noise annoyance and of aversiveness were obtained from 49 participants with moderate sensorineural hearing loss before fitting and after 3 weeks of hearing aid use. Findings were compared to measures obtained from normal-hearing listeners. Perceived annoyance and aversiveness increased with amplification. Annoyance and aversiveness with the hearing aid approximated normal perception. The results of this investigation suggest the need for counseling patients about realistic expectations related to annoyance and aversiveness of sounds at the time of hearing aid fitting.

Keywords: annoyance; amplification; digital noise reduction; aversiveness

The majority of persons with mild-to-moderate hearing loss who are pursuing amplification indicate that their primary problem is hearing in noise.[1,2] In addition, hearing aid wearers indicate that the number one improvement they would like to see in hearing aid development would be improvement in understanding in noise.[3] A variety of hearing aid signal-processing techniques has been introduced to tackle this problem. Currently, most new hearing aids are introduced with some type of proprietary noise-reduction algorithm for this purpose.[4-6] The goal of these algorithms is to improve speech intelligibility in noise or to provide comfort in noisy situations or both. Bentler et al[7,8] and Walden et al[9] described increased comfort or ease of listening with a variety of noise-reduction schemes (sometimes in combination with other features) while finding a lack of evidence for improvement in speech intelligibility. Similar findings have been reported by Ricketts and Hornsby.[10] Alcantara et al[11] did not find evidence for improved comfort or performance when testing a noise-reduction system. These researchers used different digital noise reduction (DNR) technology, which could have influenced their findings.

Although it often has been documented that background noise is a reason people stop using hearing aids, there are surprisingly few studies that have systematically examined noise annoyance perceived through hearing aids. Recently, a test related to noise annoyance, the Acceptable Noise Level Test (ANLT), has been used in hearing aid research.[12] The ANLT assesses the highest level of noise that a person finds acceptable when that noise is presented simultaneously with speech presented at the patient's maximum comfort level. The difference between the patient's maximum comfort level and the highest

From the Department of Communication Science and Disorders, University of Pittsburgh, Pittsburgh, Pennsylvania (CVP), the Department of Speech Pathology and Audiology, University of Iowa, Iowa City, Iowa (RB), and the Department of Hearing and Speech Sciences, Vanderbilt University School of Medicine, Nashville, Tennessee (HGM).

Address correspondence to: Catherine V. Palmer, University of Pittsburgh, 4033 Forbes Tower, Pittsburgh, PA 15260; e-mail: palmercv@upmc.edu.

level of background noise is termed the acceptable noise level, or ANL. Research has shown that ANLs are the same for normal-hearing and hearing-impaired persons and, in general, range from around –2 dB to 30 dB, with a mean ANL of 10 to 11 dB.[12] There are laboratory data suggesting that both directional microphone technology and DNR can reduce the aided ANL.[13,14] Moreover, there is limited research showing that a patient's ANL is related to hearing aid satisfaction; that is, the smaller the ANL, the greater the probability that the patient will be a successful hearing aid user.[15] Nabelek,[12] however, reports that at least for normal-hearing listeners, there is very little correlation between the subjective report of background noise in the real world and the acceptance of background noise when listening to speech in background noise.

The aversiveness of sound is another aspect of listening that may be related to annoyance and is a subscale of the Abbreviated Profile of Hearing Aid Benefit (APHAB).[16] Several investigations of modern hearing aids have used this subscale as an outcome measure. In general, these studies have shown that even with hearing aids with noise reduction, hearing aid users report a greater number of aversiveness problems when they wear hearing aids than when they were unaided.[17-21]

It was of interest in the present investigation to evaluate the perception of annoyance directly rather than assuming that just because a sound is aversive, it may be annoying. Many aversive sounds are short (eg, a slammed door) or are warning signals (eg, a siren), whereas sounds perceived as annoying may have a longer duration or not be particularly meaningful. Moreover, many of the aversive items on the aversiveness scale of the APHAB would not be treated as noise by most DNR algorithms.

At present, we have limited information about the perceived annoyance of sound. It is important to understand how both hearing loss and amplification affect perceived annoyance. Hearing aid users may expect that if they wear a hearing aid with DNR in a noisy environment, that the amplified sound will not be annoying to them. It is also important to know how hearing-impaired listeners' perception of noise through the hearing aid compares to the perception of normal-hearing listeners. With advancements in hearing aid technology, it seems that a return to normal performance or perception may be the most appropriate comparison condition for the evaluation of hearing aid technology and for the creation of appropriate counseling techniques for new hearing aid users.

The goals of this investigation were (1) to determine the effect of a specific DNR system on the perception of noise annoyance and aversiveness by hearing aid users and (2) to compare perceived noise annoyance and aversiveness of the hearing aid users to perceived noise annoyance and aversiveness of normal-hearing listeners. Annoyance ratings were collected from hearing-impaired listeners in a laboratory setting with and without Siemens Triano (Siemens Hearing Instruments Inc, Piscataway, NJ) hearing aids (set to maximum DNR and with the omnidirectional microphone setting). Annoyance ratings (without a hearing aid) also were collected from a normal-hearing control group. Aversiveness ratings were collected before the hearing aid fitting and after a 3-week field trial (with the hearing aid set to include automatic adaptive directional microphones and maximum DNR). Finally, hearing aid outcome was measured with the International Outcome Inventory for Hearing Aids (IOI-HA)[22] after the field trial. The relationship between aided annoyance ratings and a hearing aid outcome measure was examined because there have been recent reports of the predictive nature of noise acceptance on hearing aid outcome.[15]

Methods

Participants

Participants with hearing loss were eligible for inclusion in this study if they met the following criteria: (1) downward-sloping bilateral sensorineural (air/bone gap, <10 dB) hearing loss, (2) hearing levels no better than 20 dB hearing level (HL)[23] at 500 Hz and no worse than 75 dB HL at 3000 Hz, (3) hearing symmetry within 15 to 20 dB, and (4) no cognitive, medical, or language-based disorder that would preclude reading and understanding directions, consent form agreement, or other experimental tasks. The participant was considered a new user of amplification if he or she reported fewer than 60 days of hearing aid use within the past 12 months and an experienced user if he or she had at least 6 months of regular use in the past 12 months.

Forty-nine persons with hearing loss participated in this study, which was part of a larger clinical trial (25 from the University of Iowa site and 24 from the University of Pittsburgh site). The subject pool consisted of 22 women and 27 men. The mean age of the participants was 62.1 years (SD, 13.7; range, 27-85 years). There were no significant differences in age between the University of Pittsburgh and University of Iowa participants. Eighteen of the participants were new hearing aid users, and 31 were experienced hearing aid users. All of the experienced hearing aid users had been wearing wide-dynamic-range compression instruments; many had used hearing aids with directional microphones.

An additional 30 participants (10 men and 20 women) with normal hearing thresholds (<15 dB HL, 250-8000 Hz) and a mean age of 34.8 years (SD, 11.9) participated in the annoyance rating portion of the experiment. The group with normal hearing was not matched by age to the experimental group because the goal was to have a sample of young, normal-hearing subjects whose abilities could be characterized as the ultimate goal of a successful hearing aid fitting (a return to young, normal function).

Procedures

The equipment and calibration for all aspects of the study were identical between the 2 research sites. Audiometric evaluations were conducted for all subjects. Pure-tone thresholds were obtained for the frequencies of 250, 500, 1000, 2000, 4000, and 8000 Hz, using a GSI-16 audiometer.[23] Pure-tone signals were presented through ER-3A insert earphones. Thresholds for the subjects with hearing loss ranged from 20 dB HL to 75 dB HL from 500 to 3000 Hz, with bilateral symmetry within 15 to 20 dB for any given frequency (refer to Figure 1 for the mean pure-tone thresholds). There were no significant differences in audiometric variables at the .01 level between the University of Pittsburgh and the University of Iowa participants. Ear-mold impressions were taken bilaterally, and acrylic ear molds with pressure vents were ordered for each participant with hearing loss. Vents were limited to pressure venting to preserve the directionality of the instruments in various portions of this study in which directional benefit was of interest.

Hearing Aids

The Siemens Triano (Siemens Hearing Instruments Inc) behind-the-ear hearing aids were used in this investigation. The Triano-3 is a second-order, 3-microphone directional design. The microphone response of the hearing aid can be set to omnidirectional, fixed directional, or adaptive directional. The hearing aid uses input (AGCi) and output compressors (AGCo). The hearing aid includes 16 individual channels that employ AGCi compression with an attack time (TA) of 5 milliseconds and a release time (TR) of 90 milliseconds for short duration signals and a TA of 900 milliseconds and a TR of 1.5 seconds for longer duration signals. AGCi compression kneepoints varied as a function of hearing loss and dynamic range but generally fell in the range of 40 to 50 dB sound pressure level (SPL). The AGCo serves as an output limiter, with a TA of <0.5 milliseconds and a TR of 100 milliseconds.

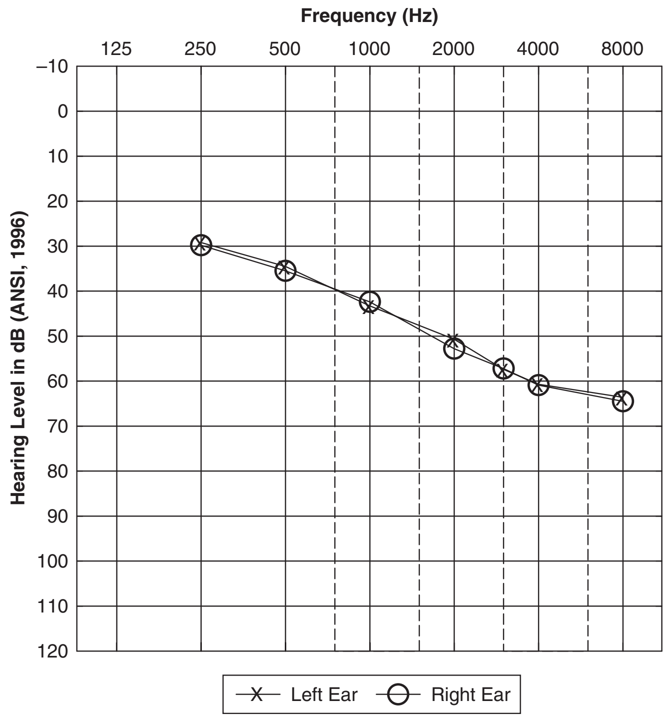

Figure 1. Mean thresholds (±1 SD) for the participants with hearing loss.

The DNR system of this instrument has 2 components. The first is a modulation-based algorithm with relatively slow onset (~5 seconds). The second algorithm, operating simultaneously, is a fast-acting Wiener filter (adaptive, 10 milliseconds). The strength of the channel-specific gain reduction for these DNR algorithms can be adjusted in the fitting software.

The subjects were fitted bilaterally with the hearing aids; gain and output were programmed using the manufacturer-implemented National Acoustics

Laboratory–nonlinear version 1 (NAL-NL1) fitting strategy.[24] Frequency-specific loudness discomfort levels were entered for output limitation, binaural summation was set to 0 dB, acclimatization was set to level 4, and ear mold condition was set to a pressure vent of 1 mm. Automatic feedback suppression was maximized. The strength of the DNR was programmed to "maximum." This setting would allow for a potential reduction of programmed gain of up to 16 to 18 dB. The amount of reduction, however, is dependent on the frequency and depth of the modulations of the input signal and the AGCi settings of the instrument. The DNR setting defaults to "MAX" in the first-fit software and likely is not adjusted by many clinicians, which is why this level was chosen. This setting would simulate a typical fitting. In the present investigation, it was not of interest to separate all of the hearing aid features that might influence annoyance but rather to evaluate a typical hearing aid fitting. All testing was conducted in the instruments' omnidirectional mode to isolate the DNR feature.

Before experimental testing, gain and output for the programmed hearing aids were verified by probe-microphone measurements (Fonix Model 6500, Frye Electronics Inc, Tigard, Ore). For the probe-microphone assessment, the noise reduction feature was turned off. Real ear aided response measures were obtained for inputs of 50, 65, and 80 dB SPL to ensure appropriate audibility through 4000 Hz, but no other attempt to alter the response for closer proximity to target values was made.

Annoyance Ratings

Subjects listened to traffic noise (73.6 dBA) and dinner table noise (67.1 dBA) in a sound booth. The stimuli were calibrated at the ear level of the head. The noise recordings and levels were obtained from Bakke et al.[25] These noise sources were selected because the subjects in the study by Bakke et al[25] identified these as annoying sounds. Bakke et al[25] also reported the intensity levels at which these sounds typically are received, and these levels were reproduced in the current investigation.

An identical sound field arrangement was used at each site (Figure 2). The subject was placed in the center of the 2.13 m (length) × 2.24 m (width) × 1.98 m (height) field at 0° azimuth to the single speaker located at eye level in one corner of the booth, and the remaining 6 speakers were placed at

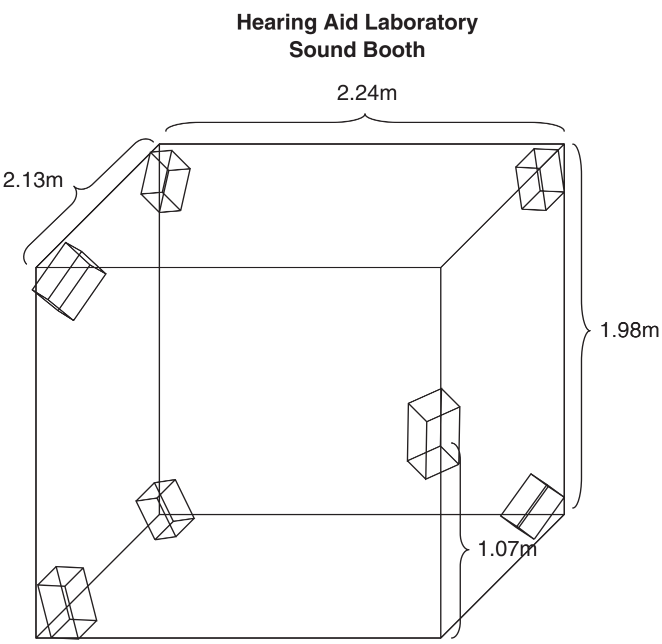

Figure 2. Schematic of the speaker set up in the listening environment. All speakers are aimed at the listener's ear.

the top and bottoms of the other 3 corners of the booth, angled to the center position.

Tannoy i5 AW point source speakers (Tannoy Limited Corp, North Lanarkshire, Scotland) were used for signal presentation. Separate Samson Servo 120 power amplifiers (Samson Technologies Corp, Syossett, NY) with separate channel attenuators were used to drive the signal to the 7 speakers. ART 355 31-band 2-channel graphic equalizers (Applied Research and Technology Inc, Rochester, NY) were used for all necessary signal shaping. A Marantz PMD 331 compact disc player (Marantz America Inc, Itasca, Ill) was used for presentation of the noises. Three 2-channel Teac P1250 compact disc players (Teac America Inc, Montebello, Calif) were used to present the noise. The same analysis equipment was used at both sites to verify each speaker, power amplifier channel, and graphic equalizer was contributing equally. Calibration was verified at each test session.

It is important to consider how the 2 experimental noise signals were classified by the hearing aid, as this would directly influence the steering of the DNR algorithms and the degree of change (if any) when DNR was implemented. To examine this, electroacoustic measurements were conducted for DNR on and DNR off for both input signals (traffic and

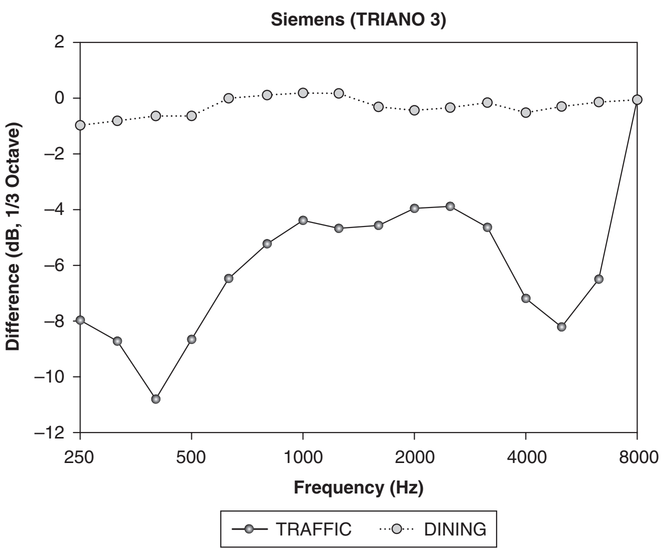

Figure 3. Electroacoustic analysis of the digital noise reduction system and the 2 listening conditions (traffic and dinner table noise). The difference in gain when the digital noise reduction is on versus off is plotted on the *y*-axis.

dinner table noise) for a sample instrument programmed based on the mean audiogram of our subjects. The input levels to the hearing aid matched the levels used in the study for annoyance ratings. The results of this testing are shown in Figure 3 as a difference in gain when DNR on is compared to DNR off. For the traffic signal, a reduction in gain across frequencies is seen when DNR is engaged. In the case of dinner table noise, however, note that the gain across frequencies for DNR on is essentially identical to the gain obtained for DNR off resulting in a difference of zero. It is clear that the modulations of the dinner table noise were such that the signal classification system of the hearing instrument classified this signal as speech.

Annoyance ratings were conducted with and without the hearing aids during 1 of 5 visits that the participant made as part of a larger study.[21,26] Annoyance was rated on a continuum from 0 (*very annoying*) to 10 (*not annoying at all*). The scale was organized in this manner so that the more positive number would correspond with the more positive perception. These measures were made without providing the listener with any real-world exposure to the new hearing aids (laboratory use only). Participants listened to 2 presentations of each noise condition (traffic and dinner table noise). The listening conditions (unaided and aided–DNR on) and the signals (traffic and dinner table noise) were counterbalanced between subjects. The 2 ratings for each noise and listening condition were averaged and then compared. The hearing aids were in an omnidirectional setting throughout this portion of the experiment.

The participants with normal hearing listened to a presentation of the traffic and dinner table noise (counterbalanced between subjects), had their hearing thresholds measured, and then returned to the booth for a second presentation of traffic and dinner table noise (counterbalanced between subjects). Because the participants with normal hearing were only exposed to 1 listening condition for each noise (normal listening), the 2 presentations were separated in time by the hearing evaluation to make sure that the second rating was not simply based on the rating they had selected moments before.

Aversiveness

Aversiveness was evaluated through the use of the APHAB.[16] An example of an item that would evaluate aversiveness would be "unexpected sounds, like a smoke detector or alarm bell, are uncomfortable." Before receiving the hearing aids, subjects completed the APHAB. The new users answered the APHAB pretest in the unaided condition, and the experienced users answered the APHAB in their current aided condition. It is questionable whether full-time hearing aid users can respond accurately to the unaided condition on the APHAB because they do not experience many of the situations in an unaided condition on a day-to-day basis.

Subjects wore the hearing aids with DNR on and set to adaptive directionality for approximately 3 weeks (this setting differs from the laboratory portion of the study in which an omnidirectional microphone setting was used). The experienced hearing aid wearers were required to leave their personal hearing aids at the laboratory during this part of the study to ensure use of the study hearing aids. At the end of the 3 weeks, subjects returned and completed the APHAB as a posttest.

International Outcome Inventory for Hearing Aids

In the same posttest visit, the subjects also completed the IOI-HA.[22] Therefore, the IOI-HA ratings

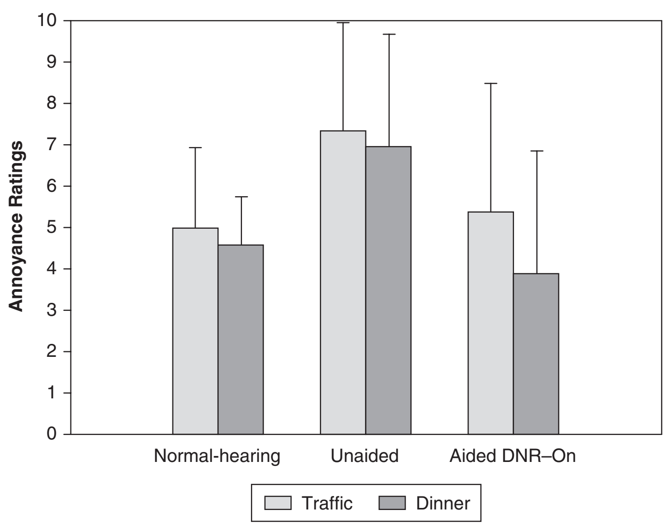

Figure 4. Mean annoyance ratings (±1 SD) for the participants with hearing loss (digital noise reduction [DNR] as employed by the Siemens Triano [Siemens Hearing Instruments Inc, Piscataway, NJ] and unaided) and for the participants with normal hearing.

were a result of the participants' experience with the automatic adaptive directional microphones and maximum DNR during the field trial. These data were collected to facilitate the evaluation of the predictive nature of the laboratory annoyance ratings with an outcome measure that includes evaluation of use, benefit, and satisfaction.

Results

Annoyance Ratings

The participants with hearing loss rated 2 listening conditions (unaided and maximum noise reduction) in 2 types of noise (traffic and dinner table noise). The maximum noise reduction condition was the only aided condition and will be referred to as "the aided condition" throughout the Results and Discussion sections. The normal-hearing listeners (unaided) judged the same noises (traffic and dinner table noise) in the same test space. Figure 4 provides the mean annoyance ratings with standard deviations for each condition and each noise. Recall that 0 represents a rating of *very annoying* and 10 represents *not annoying at all*.

For the traffic noise condition, a paired-samples t test was conducted comparing the mean annoyance ratings for 2 conditions: hearing-impaired unaided and hearing-impaired aided. A significant difference was found ($P < .001$). An independent-samples t test was employed to compare the hearing-impaired participants (both in the aided and unaided conditions) to normal-hearing participants. The comparisons revealed a significant difference between the ratings for normal-hearing participants and the ratings by the hearing-impaired participants in the unaided condition ($P < .001$), with no difference found between the normal-hearing participants and the hearing-impaired participants in the aided condition. A Bonferroni adjustment was applied to the α level, resulting in an α of .0167 (.05/3) to account for the 3 comparisons.

The same analysis was conducted for the dinner table noise condition, with similar findings. A significant difference was found ($P < .001$) between the ratings of the hearing-impaired group for the unaided and aided signals. The independent-samples t test revealed a significant difference between the ratings for normal-hearing participants and the ratings by the hearing-impaired participants in the unaided condition ($P < .001$), with no difference found between the normal-hearing participants and the hearing-impaired participants in the aided condition.

It was of interest to examine whether the change (increase) in annoyance from the unaided condition to the aided condition differed as a function of signal type (dinner table vs traffic) because one signal (traffic) engaged the DNR and the other signal (dinner table) did not. A paired-samples t test was used to compare change in scores from unaided to aided in traffic noise and dinner table noise. A significant difference was found ($P < .001$) and indicated that there was less change in annoyance rating from the unaided condition to the aided condition when listening to traffic (the signal that engaged DNR in the aided condition).

Although mean data provide a great deal of information, evaluating individual data and trends in the data can be worthwhile as well. Figures 5 and 6 present the difference between unaided and aided annoyance ratings in this study for each participant as a function of hearing aid experience for each listening condition (dinner table and traffic). An increase in perceived annoyance results in a positive number, and a decrease results in a negative number. It was hypothesized that new hearing aid users might be more annoyed by the experimental noises, as the experienced users would be more accustomed to hearing them at a higher level. A Mann-Whitney

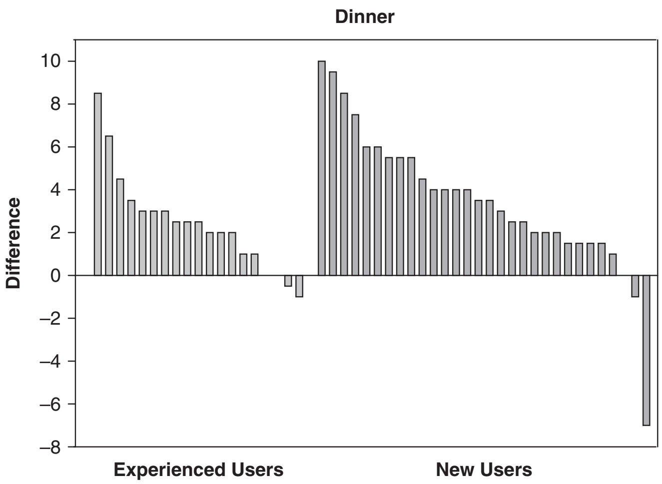

Figure 5. Individual participant data representing the change from unaided to aided annoyance ratings as a function of hearing aid experience for the dinner table noise condition. A larger positive result reveals that the participant was more annoyed with sound in the aided condition than the unaided condition.

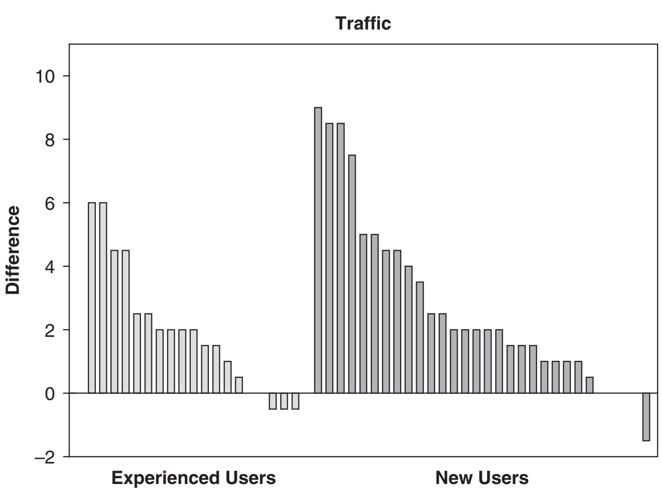

Figure 6. Individual participant data representing the change from unaided to aided annoyance ratings as a function of hearing aid experience for the traffic noise condition. A larger positive result reveals that the participant was more annoyed with sound in the aided condition than the unaided condition.

U test was used to evaluate differences between the 2 groups (experienced hearing aid users vs new hearing aid users) for each listening condition. There was no significant difference between participants with and without hearing aid experience for either the traffic or dinner table listening condition ($U = 243$, $P = .392$; $U = 209.5$, $P = .120$, respectively). This finding suggests that hearing aid experience is not a significant factor concerning annoyance from noise. We must consider, however, that the experimental hearing aids probably provided more high-frequency gain than the instruments the participants had been using, which could have influenced the findings.

Aversiveness

Results on 4 subscales of the APHAB[16] for the group with hearing loss before using the new amplification (pretest) and after using the bilateral hearing aids for 3 weeks (posttest) are shown in Figure 7. The percentiles shown on the graph are based on performance of young normal listeners.[16] All 4 subscales of the APHAB are included to illustrate that, on average, with amplification (postfitting data), hearing-impaired subjects' performance is similar to that of normal-hearing subjects across subcategories. This investigation focused on the aversiveness ratings. Note that the aversiveness subscale is the only subscale showing an increase in problems after amplification. A paired-samples *t* test was used to compare results from the pretest and posttest of the aversiveness subscale by the participants with hearing loss. The analysis revealed a significant increase ($P < .001$) in perceived aversiveness of sounds at posttest (after wearing the newly fit hearing aids) as opposed to pretest (the unaided condition for new users or the personal amplification condition for experienced users). Figure 7 shows that, on average, the participants' percentage of problems with aversive sounds has been returned to normal after hearing aid fitting (within the 95th percentile). In fact, when aided, 55% of the participants fell within the 95th percentile of young normal hearing performance for self-perception of aversiveness. As noted above, this return to normal is a worsening of problems.

Annoyance as a Predictive Measure of Outcome

The correlation between average aided annoyance and questions 1, 2, and 4 of the IOI-HA[22] was evaluated to assess the potential for using annoyance ratings to predict outcome. These 3 questions from the IOI-HA evaluate use (1: "On an average day,

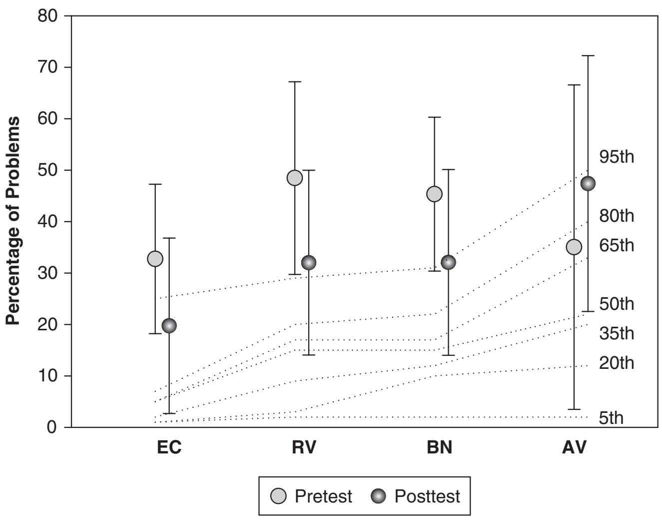

Figure 7. Mean pretest and posttest Abbreviated Profile of Hearing Aid Benefit (APHAB) results (±2 SD) from the group with hearing loss after using bilateral hearing aids for approximately 3 weeks. The performance percentiles are depicted as dotted lines.[16] EC = ease of communication; RV = reverberation; BN = background noise; AV = aversiveness.

how many hours did you use the hearing aids?"), benefit (2: "Over the past two weeks, how much have the hearing aids helped you in the situation where you wanted to hear better?"), and satisfaction (4: "Considering everything, do you think your present hearing aids are worth the trouble?"), respectively. A Spearman correlation revealed no significant relationship between aided annoyance ratings and the individual IOI-HA items addressing use, benefit, or satisfaction (P = .888, .652, .892, respectively).

Discussion

The results show that for the hearing aid used in the current study, annoyance and aversiveness increase with amplification. Furthermore, the aided perception of annoyance and aversiveness are similar to those of normal-hearing listeners. The unaided ratings of the hearing-impaired listeners showed lower annoyance in the test environments (traffic noise, dinner table noise). Annoyance is influenced by the audibility of the noise. For instance, there is a significant positive correlation between level and annoyance rating,[27,28] especially in the high frequencies. Therefore, it is not surprising that the unaided condition that produces a less audible signal (quieter in general) than the aided condition was found to be less annoying to these listeners with hearing loss.

Recall from Figure 3 that the classification system of the hearing aid categorized traffic noise and the dinner table noise differently, resulting in a moderate gain reduction for the traffic noise and no gain reduction for the dinner table noise. Indeed, the change in annoyance perception revealed less annoyance for the traffic condition than for the dinner table condition. Although a DNR-off condition was not included in this investigation because the interest was in the default setting that one can assume would be the most common setting for most hearing aid users, in essence the processing of the dinner table noise is equivalent to a DNR-off condition. Based on the differences between the unaided and aided annoyance ratings for traffic noise as compared to the unaided and aided annoyance ratings for the dinner table noise, DNR appears to have had a positive impact on the annoyance perception of the type of noise it was meant to reduce. This finding would be considered valuable when recommending a DNR feature to a potential hearing aid user. However, perhaps the most important message to the new hearing aid user will involve realistic expectations involving annoying signals. Amplification increased annoyance ratings; this was evident whether the DNR was present or absent. It is important for the hearing aid user to understand that the noises perceived as annoying through the hearing aid are also perceived as annoying by normal-hearing listeners. The hearing aid user may expect that the hearing aid (especially one with DNR) should not make sounds more annoying. He or she most likely will not remember just how annoying some sounds can be when heard appropriately. Thus, careful counseling about what to expect when hearing noise through the hearing aid is essential.

The aversiveness data illustrate that persons with hearing loss rate aversive sounds as less aversive when they listen to them in the unaided or personal hearing aid condition than when they listen through newly fitted hearing aids producing audible signals at soft, moderate, and loud levels across frequencies. In fact Walden et al suggested that "Persons with long-term acquired hearing loss may develop unrealistic expectations regarding the intrinsic aversiveness of many loud sounds encountered in daily life."[29(p74)] The data from both the annoyance and the aversiveness tasks support this notion. The annoyance ratings were obtained in the omnidirectional setting with DNR set to maximum, whereas the posttest aversiveness data were collected after use of the hearing aids in automatic adaptive directional mode with maximum DNR. Although these different settings may not allow for direct comparison, it is unlikely that engaging the directional microphone would have altered the annoyance results because the sounds in the annoyance rating task were coming from the front, back, and sides of the listener.

Subjects rated sound as more annoying and more aversive when listening through hearing aids. If one only compares these results with pretest (unaided) results, it would be tempting to describe amplification as increasing annoyance or the perception of aversiveness, which would be considered a negative by-product of appropriate amplification. In reality, if these results are compared to the performance of persons with normal hearing on the same measures, one finds that the appropriate amplification has returned a normal perception of these annoying and aversive sounds.

As discussed earlier, there are some data to suggest that the level of acceptance of background noise (the clinically measured ANL) is related to satisfaction with hearing aid use.[15] Although ratings of annoyance for background noise may be a different perceptual measure than ratings of "acceptable levels of background noise," the annoyance ratings given by our participants were compared to the outcome assessments of overall use, benefit, and satisfaction of the hearing aids in the real world. The statistical evaluation revealed no significant relationship between aided annoyance ratings and any of the 3 individual items on the outcome measure. Nabelek[12] indicated that ANL may be an important clinical measure because data from her laboratory (persons with normal hearing sensitivity) had revealed that there was little correlation between the subjective report of preference for background noise during day-to-day activity and acceptance of background noise. Although there are data to indicate that measured background noise acceptance[15] correlates with hearing aid satisfaction, the data in this study do not support that relationship when subjective annoyance rating is used. This finding supports the notion that subjective annoyance ratings and measured background noise acceptance may be evaluating different perceptual areas.

The data from both the annoyance ratings and the aversiveness ratings, although based on slightly different hearing aid configurations (omnidirectional with maximum DNR and automatic adaptive directional with maximum DNR, respectively), suggest that both new and experienced hearing aid users getting new hearing aids should be counseled to understand that increased audibility (regardless of special signal-processing features) will result in a more normal perception of annoying and aversive sounds. This more normal perception will not be similar to the new hearing aid user's previous perception and may require an adjustment period.

The results of this study may be somewhat dependent on the specific signal processing employed in the hearing aids used in this study and on the types of noises used for the annoyance ratings. Further research using the experimental approach taken here would be useful in examining how the perception of noise changes with hearing aids containing different DNR algorithms and how this perception compares to that of normal-hearing listeners.

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